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ABSTRACT

A new framework for designing qualitative studies is described to optimize the emergence, representation and presentation of insights. The framework, called Reflection Methodology, is presented as a "Conversational Paradigm" that includes four components--interviewer (researcher as participant); child, task situation, and observing technology (including a second researcher as external observer)--in three phases--reflection/performance, judgmental reflection question, and reflection simulation. The involvement of the researcher team embodies the "complementarity" of the wholistic perspective with the separation perspective. The core subsystem within the paradigm is the child as an autonomous living system interacting with a task. The task, traditionally seen as input from the environment, is in contrast a perturbation and also a perturbation within the interviewer system. Accordingly, the conversational system evolves around the common perturbation--the task. It is through the joint participation of the child-task system and the interviewer-task system in the larger conversational system that the task gains any living meaning as an aspect of a larger social system. Descriptions of the task are representations of order which emerges from Reflection Methodology as a conversational system to provide a framework for clinical studies that are becoming central in mathematics education. Methods of a 1985 study in partitioning by children using Reflection Methodology are described to exemplify the Conversational Paradigm. (PN)

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TOWARD A SELF-REFERENTIAL THEORY OF PARTITIONING: METHODOLOGICAL CONSIDERATIONS

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Presented at the
Annual Meeting of the
American Educational Research Association

ABSTRACT In this paper we describe a new framework for the design of qualitative studies that optimize the emergence, representation and presentation of insights. The framework is called Reflection Methodology and is presented here in the explicit form of a "Conversational Paradigm" for educational research.

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TOWARD A SELF-REFERENTIAL THEORY OF PARTITIONING:
METHODOLOGICAL CONSIDERATIONS

INTRODUCTION

Over the last decade there has been a shift in educational research toward what are often called "qualitative" studies. Despite the enthusiasm, the lack of precisely worked out frameworks for conducting such studies is problematic. Kilpatrick (1986) succinctly identifies the problem:

> A major problem is that, whereas the canons for laboratory investigations are clear and well developed, the canons for field investigations are just beginning to be laid down. In the absence of specified criteria, of course, anything goes. Flocks of wide-eyed researchers armed with tape recorders and note pads are running out to live in classrooms for a few weeks, hoping that insight will follow. But without any framework for analyzing what they find, they may not find very much worth hearing about (p. 2).

In this paper we would like to describe a new framework which has helped us design qualitative studies that optimize the emergence, representation and analysis of new patterns (insights). The framework, which we call Reflection Methodology, evolved over the last few years (Pothier & Sawada, 1983, 1984a, 1984b), and is presented here as a "Conversational Paradigm".

Background to the Paradigm

The role of the child in the 1983 study was strictly as a performer in a task situation set within a clinical interview. Interpreting the child's performance gave rise to the theory of partitioning reported in 1983.

In the following two studies (1984a, 1984b) the methodology changed significantly: no longer did children simply try to partition an object into a specified number of equal parts; instead they were first asked a question about the task before being asked to solve it. The question was this, "With how many children would it be easy to share this cookie so each would have as much?" When the child indicated a number, he/she was asked to do the partitioning for that number of children. In this way, two kinds of data were generated: (1) the same kind of performance data as generated in the 1983 study, and as well (2) awareness data which tapped the child's ability to assess the difficulty of a task (i.e., make a judgment) before attempting to do it. In a minor way, then, the child participated in constructing the tasks which he/she would then

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solve, thus making the methodology self-reflective.

As reported in Pothier & Sawada (1984a), the awareness (judgmental) data as well as the performance data corroborated the 5-Level theory generated from the 1983 performance data. In a way, the child's direct assessment of the difficulty of partitioning tasks gave a different yet isomorphic interpretation of partitioning. This realization suggested a methodological theme that can be captured by the general question, "What role can be played by children as "informants" concerning their own partitioning performance, and how can such self-reference be used to enrich the theory derived by the researcher from the performance data?"

In the human sciences the subjects in a research study are intelligent living beings (living systems) and therefore "make sense" of (reflect upon) the data situation as well as perform in it. In another manner of speaking then, the question is this, "What role is there for the awareness that children have of the data situation in helping the researcher to theoretically explain their performance in such situations?" However, developing a role that would see the child as a "co-investigator" as well as a subject in the research would run counter to traditional methodological ideology. In particular, from the Campbell and Stanley (1967) perspective, such a duality of role for the child would produce alarming "threats to validity."

Thus, new methodological foundations need to be constructed if we are to directly incorporate the child's awareness into the construction of theory, or the interpretation of data. Merely translating the Campbell & Stanley criteria by coining new phrases such as "credibility" for internal validity or "dependability" for reliability as done by Guba (1981) will lead only to confusion (Smith & Heshusius, 1986). However, unlike Smith & Heshusius, we do not see the "quantitative" and "qualitative" paradigms as being mutually exclusive. To the extent that our awareness data corroborated and enhanced the theory based on the performance data (Pothier & Sawada, 1984), there is empirical support for a methodogicial stance that might see a "complementarity" between these types of data.

FOUNDATIONS OF REFLECTION METHODOLOGY

In Reflection Methodology there is a strong recognition of children as spontaneous, autonomous, energetic "unities" that not only <u>respond</u> to stimuli but also <u>initiate</u> action of their own often independent of external stimulation. Conventionally, in research designs of the Campbell & Stanley (1967) type, almost exclusive attention is paid to subjects as <u>responders.</u> Subjects are explicitly and precisely extracted from their "natural" environments and randomly assigned (placed

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into) rigorously controlled experimental environments (treatments). The ontological assumption underlying the paradigm is this: The child's existence is not in any critical way destroyed by treating child and environment as two independent variables.

Contrastingly, in Reflection Methodology, there is no clear separation of person from environment: the person and his environment (including other people) is taken as a whole, as ONE system. It is in this stance that Reflection Methodology takes on a fundamentally different character from the Campbell & Stanley perspective. In Reflection Methodology, the person/environment system is a unity, the wholeness of a system (Bateson, 1979; Bohm, 1980; Bronowski, 1978; Maturana & Varela, 1980).

Emergence of Unity

The unity within the person/environment system cannot be accounted for by considering the properties of its components alone. The unity (or synonymously, the identity or the coherence) of a person/environment system hinges critically on the fact that unity does indeed emerge from the system taken as a whole. The emergence of unity is crucial in Reflection Methodology. It is also crucial for "clinical interview" methods and for "think aloud" techniques and, indeed, for qualitative studies in general because in all these methods there is a fundamental trust (hope) that insights will somehow emerge. But hope alone is not enough. It is therefore critical that Reflection Methodology be grounded in a science of emerging order.

Order Through Fluctuations

The study of the spontaneous emergence of order within natural systems has been motivated, in part, by the discovery in chemical systems of unexpected patterns in situations of turbulence, particularly in the pioneering research of Ilya Prigogine (1980) who refers to his work as the theory of Dissipative Structures (the name itself suggests that as the given order dissipates, new structure emerges).

Prigogine's study of new patterns as they emerge out of situations of turbulence has led him to see universality in the spontaneity of man within the natural world. Prigogine & Stengers (1984) state it this way.

> This leads to a new view of matter in which matter is no longer the passive substance described in the mechanistic world view but is associated with spontaneous activity. This change is so profound that . . . we can really speak about a new dialogue of man with nature. (p. 9)

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Although order does not emerge out of chaotic situations of all kinds, it does spontaneously configure in special yet not uncommon circumstances. In general, these circumstances can be described as open systems. By this is meant a system that exchanges matter or energy. In cognitive systems, this is usually interpeted as a system (e.g., the mind of a pupil) that exchanges information (e.g., by engaging in a conversation with the researcher or with another pupil or by reading a book).

Dissipative Structure theory tells us that of the three types of open systems: (1) those at-equilibrium within its environment, (2) those near-equilibrium within its environment, and (3) those far-from-equilibrium within its environment, only the third type leads spontaneously to the emergence of higher order. The other types may lead to order, but it will not be an order that emerges spontaneously.

To give a concrete sense of the differences among these types of open systems we quote from Toffler's Foreword to Prigogine & Stengers (1984):

> Imagine a primitive tribe. If its birthrate and death rate are equal, the size of the population remains stable. Assuming adequate food and other resources, the tribe forms part of a local system in ecological equilibrium.
>
> Now increase the birthrate. A few additional births (without an equivalent number of deaths) might have little effect. The system may move to a near-equilibrium state. Nothing much happens. It takes a big jolt to produce big consequences in systems that are in equilibrial or near-equilibrial states. But if the birthrate should suddenly soar, the system is pushed into a far-from-equilibrium condition, and here non-linear relationships prevail. In this state, systems do strange things. They become inordinately sensitive to external influences. Small inputs yield huge, startling effects. The entire system may reorganize itself in ways that strike us as bizarre. (p. xvi)

Suppose that this primitive tribe is, as it were, a group of students working on partitioning tasks, and suppose further that processes of conversation (communication in general) are substituted for processes of birthrate. Now, if conversational processes were to "suddenly soar" (e.g., if conversations were to suddenly become intriguingly alive), then the group may "become inordinately sensitive to external influences" (such as the researcher), and even "small inputs" (such as a remark from a fellow student) might serve as a spark which may "yield huge, startling effects" (such as a creative solution to a partitioning problem).

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Thus, it is in open systems which are far-from-equilibrium that new order emerges spontaneously. When systems propel themselves through recursive feedback loops to a far-from-equilibrium state they are subject to spontaneous, dramatic reorganizations of structure. The role of recursion is pervasive in the emergence of new order. It appears in the form of cross-catalytic and auto-catalytic feedback and feedforward loops which, in a compounding way, drives the system nonlinearly to a highly sensitive state far-from-equilibrium. In this situation, information not normally sensed can have dramatic effects. (See Sawada & Caley (1985) for further discussion of Dissipative Structures.)

If, as in an experiment of the Campbell & Stanley variety, a conversational group (as an existing unity) is "surgically" separated from its natural environment and thrust into a new environment without any regard for its unity (integrity), the group degenerates to a primitive form of equilibrium. As a system at- or near-equilibrium, the "truncated" conversation is a unity no more; the group disintegrates into a collection of individuals (components with no cross-recursion; a state of increased entropy). Higher order will not spontaneously emerge in a situation of this kind. Insights are not likely to emerge.

The unity of a system can often be destroyed in much less blatant ways. For example, when an outside "authority" figure (such as the principal) enters into the physical space of a lively conversation (such as a clinical interview between researcher and children), his/her mere presence may interrupt the recursive interactions to such an extent that the conversation dissipates into a mere collection of individuals (i.e, the unity is destroyed). This would be an instance of the destruction of the autonomy of a conversational system; of driving it to the equilibrium (entropic) state of a random collection of particles.

Autonomy in Living Systems

The foregoing remarks concerning the operation of recursion in the spontaneous emergence of order has highlighted the significance of unity: A conversational system without unity would simply be information transfer (input and output) and would be completely within the now classic conception of information in which entropy can only increase (Shannon and Weaver,1949). Unity in such a context would be impossible. In what context is it possible? Consider these remarks from Varela (1979):

> . . .autonomous systems are organizationally closed. That is, their organization is characterized by processes such that (1) the processes are related as a network so that they recursively depend on each other in the generation and realization of the processes themselves, and (2) they

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> constitute the system as a unity recognizable in the space (domain) in which the processes exist. (p. 55).

It seems that unity is a property of systems that are "organizationally closed", systems that are "autonomous". Varela continues:

> In general, organizational closure can be viewed as providing the mechanism through which emergent properties of new units arise, and thus as the "hinges" for the hierarchy of levels in natural systems. Thus, one point of view toward wholeness is that it co-occurs with interesting emergent properties at some level. (p. 103)

In view of Varela's remarks, we suggest that the theory of autonomous living systems provides an appropriate "framework" for the emergence of insight in clinical studies (and in qualitative studies in general). This framework is intuitively appropriate since autonomy can only be built on inner processes, i.e., spontaneity can only arise from within; it cannot be imposed from without. In this sense, the child as an autonomous living system is the central subsystem in Reflection Methodology.

Organizational closure also implies a more participatory role for the researcher (Varela, 1979):

> In the characterization of organizational closure, nothing prevents the observer himself from being part of the process of specifying the system, not only by describing it, but by being one link in the network of processes that defines the system. This situation is peculiar in that the describer cannot step outside of the unity to consider its boundaries and environment simultaneously, but it is associated with the unit's functioning always as a determining component. Such situations, to which most of the autonomous social systems belong, are characterized by a dynamics in which the very description of the system makes the system different. (p. 57)

A conversation is a paradigmatic case of an autonomous social system in which the observer participates in the system. The Reflection Methodology used in our study takes the form of a Conversational Paradigm as a living autonomous social system, and focuses on the recursively participatory processes of researcher involvement giving rise to several levels of conversation all revolving around the living system that is the child. (For an excellent discussion of autonomy in living systems and of autopoiesis in the cognitive domain see Maturana & Varela (1980), Varela (1979). For a discussion of autonomy in cybernetic terms see Sawada & Caley (1986).)

AN EXAMPLE OF THE CONVERSATIONAL PARADIGM

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A study in partitioning using Reflection Methodology was conducted in 1985. The methods of this study are described here in some detail as an example of the Conversational Paradigm.

The key operation in Reflection Methodology is self-reference. It is actualized through the processes of reflection and recursion in a conversational system: If after explicitly reflecting upon their partitioning performance, children were to return to the partitioning task, the reflection and the meaning such reflection might generate, could, in a recursive sense, inform further partitioning; this upon reflection, could generate more meaning that could inform further partitioning; and this in turn upon further reflection would become part of still further partitioning; and this. . . . This would be an example of a child having a conversation with him/herself while interacting with a task (a Child-Task Conversational System). Accordingly, a data acquisition plan involving a recursive cycling of reflection and performance was developed.

Phase_I The first phase consisted of the initial judgmental reflection session as incorporated in the 1984 studies (briefly described earlier). In essence, Phase I allowed a direct sharing of thoughts concerning what constitutes easy partitioning.

Phase_II The second phase followed the child's completion of each partitioning task and provided two opportunites for the child to reflect: firstly upon judgmental decisions, and secondly upon partitioning performance. These aspects of reflection often merged together.

Phase_III The third phase, with the use of videotape, involved the child in reflecting upon the entire data session (including earlier reflection sessions) as replayed on tape.

Implementing_the_Three-Phase_plan

All data collection sessions were video and audio taped. Children were individually interviewed in clinical fashion in a simulated situation described as a birthday party. Both researchers were always present; one as the interviewer (participant-observer), the other as recording technician (observer-participant). Both researchers played both roles at different times. At all times, however, the recording technician had the option of participating in the interviewing as well as taking notes and operating the "observational" hardware.

At the birthday party, simulated giant cookies of various shapes made of colorful styrofoam glued to a cardboard plate were to be shared with children at the party, each child at the

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party being represented by a miniature doll. The real child was NOT one of the children at the party. Since the party and the cakes and the children at the party (dolls) were all simulated, the real child is an observer of the party and as such assumes a role of a commentator and arranger of the party (in effect, the context for a role as co-investigator is being established). Concomitantly, the child is also the one who partitions the cookies. Thus the child is simultaneously arranger, partitioner, and commentator. These roles interact in a synergistic manner (Corning, 1983).

A particular cookie was placed on the table. The child was asked, "With how many children would it be easy to share this cookie so each would have as much?" (an example of Phase I reflection). When the child indicated a number of children, the interviewer placed that number of dolls beside the cookie. The child was then asked to "cut the cookie so each doll will have as much." The cuts on the cookie were indicated by laying thin sticks on the top of the cake (Phase I performance). A supply of sticks in three different lengths were freely and conveniently available on the table to indicate cuts. The procedures thus far are identical to those used in the 1984 studies.

If the child completed the partitioning without difficulty he/she was asked, "How did you know it was going to be so easy (or something to this effect)?" (This is a Phase II, judgmental reflection question.) If, on the other hand the child experienced noticeable difficulty in completing the "easy" partitioning, he/she was asked, "Was that as easy as you thought it would be? Can you tell me what made it difficult?" (This is an example of a Phase II, performance reflection question.) Since these reflection questions were completely contingent upon each child's judgment and/or performance, they were not uttered in mechanical verbatim. Instead they were tailored to each individual situation and sometimes were postponed to a Phase III setting. Such flexibility is a recognition of the spontaneity in each child and in the researchers.

After approximately 10-30 minutes of clinical interaction (i.e., after partitioning cookies in the shape of a square, an equilateral triangle, a heart, and a parallelogram), the video tape was re-wound and viewed by the child as part of a session of stimulated recall, the setting for Phase III reflection. Since the stimulated recall technique is well known (see for example, Bloom, 1946) it will not be described here. Suffice it to say that this technique provides a sensitive catalytic environment within which the child could participate reflectively as co-investigator by observing him/herself in action on tape and commenting on any aspect he or the researcher identified by pressing the "pause" button (Phase III reflection). The child was encouraged to press the pause button (remote-controlled) whenever he/she wished to say or do

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something. The clinician also paused the tape whenever a probing question seemed appropriate. The task materials were freely available on the table throughout this session to encourage children to demonstrate (after pressing the pause button) their concerns (Phase III performance) as well as speak to them.

Phase III reflection, by using video tape, "simulated" the data situation, thus enabling the child to externalize him/herself from the partitioning task and therefore to "re-enter" his/her own behavior while at the same time "re-living" it. In this way, Phase III reflection explicitly made the data self-referential in a recursive manner. With the child controlling a pause button, entry into the "commentatory mode" of reflection was facilitated. Furthermore, provision of the task materials on the table at the time of replay allowed the child, upon pressing the pause button, to in effect "re-enter real time," and to "re-do" his partitioning in the "demonstration mode" of reflection by clarifying with the aid of the materials what he did, or might have done, or should have done, or perhaps "meant to do" the first time. All children made use of this opportunity to re-enter real time. Phase III sessions were also videotaped, but these were not viewed by the child. The recursion had to stop somewhere.

Within a day, the child was invited back to the data setting to complete the remaining 3 tasks (partitioning a regular pentagon, a regular 5-pointed star, and a regular hexagon) and the associated reflection sessions.

REFLECTION ON REFLECTION METHODOLOGY

The Conversational Paradigm used in the study included four components: interviewer (researcher as participant), child, task situation, and observing technology (including a second researcher as external observer). The involvement of the researcher team simultaneously as participant and as external observer embodied the complementarity of the wholistic perspective with the separation perspective. The core subsystem within the paradigm was the child as an autonomous living system interacting with a partitioning task. The task, traditionally seen as an "input" from the environment, is in contrast a "perturbation" [Note 1] within the child system. Since the interviewer is an autonomous living system as well, the task is also a perturbation within the interviewer system. Accordingly, the conversational system evolves around the common perturbation (the task). The commonality of the task, although seemingly the "same" for both child and interviewer (from the traditional point of view it is seen "objectively" as the same task) is in fact different within the two systems. It is only through the joint participation of the child-task system and the interviewer-task system in the larger conversational system that

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the task gains any living meaning as an aspect of a larger social system (see Pask, 1975 for further and alternate analyses of these conversational possibilities).

The above remarks can be specified more clearly by listing some key subsystems of Conversational Paradigm:

1. Child (C)
2. Interviewer (I)
3. Observing technology (O)
4 Task T
5. Child-Task (C-T)
6. Interviewer-Task (I-T)
7. Child-Task-Interviewer [(C-T)-(I-T)]
8. Child-Task-Interviewer-Observing technology {[(C-T)-(I-T)]-[O]}

Several points concerning the above listing should be noted:

1. Several subsystems have not been listed (e.g., (C-O)). These subsystems are as important as those listed but an exhaustive listing is not our purpose here.

2. Parentheses play a special role in indicating "systeming". For example, the child is indicated by (C) in preference to C to indicate that the child is an "autonomous living system". On the other hand, the task is indicated by T rather than (T) since the partitioning tasks, although they can be analyzed as a system by an external observer, are not "autonomous living systems." However, the larger child-task system is again a unity and is indicated by parentheses (C-T). As well, levels of systeming within more complex systems are indicated by parenthetical subgroupings as in {[(C-T)-(I-T)]-[O]} in which there are three levels of systems: (1) the person-task systems (C-T) and (I-T), (2) the conversational system [(C-T)-(I-T)], and the observational system {[(C-T)-(I-T)]-[O]}.

3. The hyphen (-) also has a special role: it indicates a perturbational interaction. For example, the processes of systeming in (C) are different from those in (C-T) since T in (C-T) is a perturbation [Note 1] and hence in (C) the processes are dominantly those of homeostasis whereas in (C-T) there is both homeostasis and morphogenesis, the morphogenesis functioning as the emergence of new order due to the perturbational interaction (Maruyama, 1963, 1978). Also, in [(C-T)-(I-T)] the processes are largely conversational between two autonomous systems each operating as a perturbation for the other thus also giving rise to morphogenesis. As well, the components of the conversation, (C-T) and (I-T), are themselves perturbational systems of lower order.

4. The child-task-interviewer system is symbolically listed

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as [(C-T)-(I-T)] rather than (C-I-T) to explicitly indicate that the conversation is a higher order system consisting of two subsystems of lower order.

5. The clinical conversation used as a research unit in the study, i.e., [(C-T)-(I-T)], is a recursive conversational system. Through conversation, the perturbational interaction (C-T) is affected and monitored by the perturbational interaction (I-T). Likewise, and in cyclical (recursive) fashion, (I-T) is affected by and monitored by (C-T). Thus, the recursive relation between these two autonomous systems is a reciprocity of conversation that can lead to a far-from-equilibrium system [(C-T)-(I-T)] which in turn is a setting for spontaneous emergence of new order. The resulting emergence of new order (emerging properties) at the level of conversation, i.e., at the level of [(C-T)-(I-T)], is the purpose and the significance of Reflection Methodology.

6. A level of reflection higher than [(C-T)-(I-T)] occurs when the observation technology is explicitly incorporated into the conversation. This particularly happens during the video playback of the recording of [(C-T)-(I-T)]. Several recursively connected higher level conversational systems result. For example [({[C]-[(C-T)-(I-T)]})-(C-T)] would denote the child [C], while viewing the video playback of an earlier clinical interaction [(C-T)-(I-T)], pauses the playback to reflect on what transpired {[C]-[(C-T)-(I-T)]}, then interacts with the task perhaps with some new insight [({[C]-[(C-T)-(I-T)]})-(C-T)]. This is an example of Phase III Reflection.

7. As an even higher level system, {[I]-[({[C]-[(C-T)-(I-T)]})-(C-T)]} would denote the larger observational system in which the interviewer, upon viewing the child interact with the task while viewing the playback, may gain a new insight of the meaning of the original clinical interaction [(C-T)-(I-T)] or of any subsystem within Phase III reflection. Furthermore, since Phase III reflection was also videotaped, the researcher could recursively interact with insights taped in Phase III. Such recursion would constitute data analysis and takes us beyond the purposes of this paper.

8. There are several other higher systems that were reflectively constructed from the basic subsystems through Reflection Methodology, but space does not permit their elaboration here. The systems highlighted above are likely sufficient to indicate the nature of Reflection Methodology as a framework for capturing emerging order in "planned" conversational social systems.

9. Perhaps the most significant aspect of the Conversational Paradigm is that as a research methodology it need not be <u>imposed</u> on children. Rather, because social

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systems are higher level systems composed of living systems (e.g., children) that spontaneously communicate, the Conversational Paradigm as a social system is a natural extension of children. As such, our wider understanding of living systems, particularly the isomorphic relations of subsystems to higher level systems (as described for example by Miller (1978) who gives a detailed explication of living systems from cell to supernational societies), is foundational to Reflection Methodology. Our work on partitioning has had the goal of understanding the child (C) in this context. The appropriateness of the Conversational Paradigm is that the nature of (C), as an autonomous living system, is fundamentally the same as the nature of (C-T) or [(C-T)-(I-T)] and all such suprasystems of the Conversational Paradigm. Furthermore, the nature of (C) as the core subsystem is continuously revealed in greater detail as (C) participates in each higher level system. Mathematically, each higher level system in which (C) participates embodies transformations (perturbations) under which the identity (unity) of (C) may be captured as an invariant under the transformations. The reorganization (compensations) created by (C) in experiencing perturbations within the higher level systems reveal the properties of the living system (C). Capturing, representing and reporting these emerging properties is the intent of Reflection Methodology.

CLOSING REMARKS

We have given a skeletal outline of the nature of Reflection Methodology. In a forthcoming paper, we present data as it reflects the emergence of order as (C) participates in higher level conversational systems. Following Varela (1979) and Maturana & Varela (1980), our model for capturing the child's acquisition of partitioning is that of the child's mind as a "living organization" specified as a "network of interactions of components which constitute a living system as a whole." It gives a general account of partitioning as a living system and simultaneously allows us to uniquely describe each child's partitioning as an "autonomous living system." These descriptions are all representations of the order which emerges from Reflection Methodology as a conversational system. We suggest that such systems can provide a framework for the clinical studies that are becoming central in the study of mathematics education.

REFERENCE NOTES

1. The idea of distinguishing a perturbation from an input reflects the distinction between the internal (wholistic) view of a system from an external (separation) view. From the internal view a partitioning task is part of the ongoing experience of the system and is called a perturbation. From the external (observer) point of view a partitioning task is an

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input to which the system reacts, i.e., the S-R behavioral view. The internal view gives rise to a recursive living system; the external view gives rise to a description of a system as it reacts to its environment. Both views are valid, different, and isomorphic. According to Varela (1979):

> The behavioral view reduces a system to its input-output performance or behavior, and reduces the environment to inputs to the system. The effect of outputs on environment is not taken into account in this model of the system. The recursive view of a system, as expressed in the closure thesis, emphasizes the mutual interconnectedness of its components. . .That is, the behavioral view arises when emphasis is placed on the environment, and the recursive view arises when emphasis is placed on the system's internal structure.
>
> If we stress the autonomy of a system. . .then the environmental influences become perturbations (rather than inputs) which are compensated for through the underlying recursive interdependence of the system's components. (p. 86)

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